MATHEMATICAL METHOD FOR CALCULATING NECESSARY QUANTITY OF PRODUCTS FOR A GIVEN DIET USING A LIMITED ASSORTMENT OF PRODUCTS

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One of the main problems associated with space flights of long duration is that of feeding the spacecraft crew.

One aspect of this problem is the composition of the diet. The diet of the spacecraft crew must not only be of appropriate calorific value, but it must also contain specified amounts of proteins, fats and carbohydrates. Different products contain these components in different proportions, and they may be used in different amounts when diets are drawn up. The same diet of specified composition may be obtained from a different range of products, and changes in qualitative composition of the products used will result in quantitative changes in each product. There is thus a need for mathematical relationships to be deduced, by means of which a diet of specified composition and calorific value can be easily /371
selected using an available assortment of products.

Furthermore, if a diet and a definite assortment of products which may be provided on a spacecraft are specified, by using these mathematical relationships and drawing up hypothetical menus for the specified diet, the quantities of each product consumed can be determined.

The quantitative consumption of each hypothetical product, determined in this manner, can be used to calculate the sowing areas of the various crops, the necessary number of animals, and the reserves of products in the spacecraft.

In this paper a possible method which can be used to calculate a specified diet is presented to the reader.

DEFINITION OF THE PROBLEM

In order to calculate a diet of specified composition consisting of proteins, fats and carbohydrates, it is first necessary to determine the quantity of these components required in the diet. This can be done most conveniently on the basis of the required calorific value of the diet and the ratio between proteins (P), fats (F) and carbohydrates (C).

Suppose we need a diet with calorific value Q kcal and with proteins, fats, and carbohydrates in the following ratio:

$$P : F : C : = \alpha : \beta : \gamma. \quad (1)$$

Knowing the coefficients of conversion of weight of proteins, fats, and carbohydrates into calories (4.1, 9.3 and 4.1 kcal/g, respectively), we have the equation:

$$Q = 4.1B + 9.3F + 4.1C, \quad (2)$$

where B, F and C represent the weights of proteins, fats and carbohydrates, respectively, expressed in grams.

Using Eqs. (1) and (2), we can determine the values of P, F and C, which are expressed by the following equations:

$$P = \frac{Q \cdot \alpha}{(4.1\alpha + 9.3\beta + 4.1\gamma)};$$
$$F = \frac{Q \cdot \beta}{(4.1\alpha + 9.3\beta + 4.1\gamma)};$$
$$C = \frac{Q \cdot \gamma}{(4.1\alpha + 9.3\beta + 4.1\gamma)}. \quad (3)$$

If the required calorific value of the diet and the relative proportions of proteins, fats and carbohydrates in it are known or specified, the Eqs. (3) can be used to determine the quantity of each component in grams.

Often when a diet is calculated, besides specified relative proportions of proteins, fats and carbohydrates, the proportion of proteins must be subdivided into proteins of vegetable (VP) and animal (AP) origin and the proportion of fats /372
into fats of vegetable (VF) and animal (AF) origin, respectively.

In this case, having the values of P, F and C calculated by the Eqs. (3), we can determine VP and AP, and VF and AF by using the essentail relative proportions specified either as percentages or fractions.

The problem is thus to draw up a diet from available products with specified relative proportions of proteins, fats and carbohydrates and with a specified calorific value.

Let us assume that, for a specified calorific value of the diet and for specified relative proportions of proteins, fats and carbohydrates (including those of vegetable and animal origin) we need to have in the products used for the diet a grams of carbohydrates (C) b grams of fats of vegetable origin (VF), c grams of fats of animal origin (AF), d grams of proteins of vegetable origin (VP) and e grams of proteins of animal origin (AP).

We also have a series of products with known percentage contents of proteins, fats and carbohydrates which can be used in the diet. These products are given below, for convenience, in a scheme in which the percentage content of C, VF, AF, VP and AP of each product is denoted by the corresponding letters p, m, q, r and s with indices of the corresponding product.

For example: p_A represents the percentage content of carbohydrates in product A; m_B represents the percentage content of vegetable fats in product B.

With these initial data available, we need to determine the quantity of each product A, B, C, D, E, F, G and H [or some of these products] (in grams) for the specified diet.

Product g	Content				
	C	VF	AF	VP	AP
A	p_A	m_A	q_A	r_A	s_A
B	p_B	m_B	q_B	r_B	s_B
C	p_C	m_C	q_C	r_C	s_C
D	p_D	m_D	q_D	r_D	s_D
E	p_E	m_E	q_E	r_E	s_E
F	p_F	m_F	q_F	r_F	s_F
G	p_G	m_G	q_G	r_G	s_G
H	p_H	m_H	q_H	r_H	s_H
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
N	p_N	m_N	q_N	r_N	s_N

SOLUTION

To solve the problem equations must be formed using all the initial data. /373
To begin with, knowing the percentage content of the components (C; VF; AF; VP; AP) of each product we can determine the number of grams of each component in each product taken.

Let us conventionally denote the number of grams of the component taken in each product by the letter of the product with an index consisting of the initial letter of the component, for example: A_C for the number of grams of carbohydrates in A grams of the product; B_{AP} for the number of grams of animal protein in B grams of product; and so on.

In that case, starting from the data in Table 1 and taking into consideration the remarks made above, we have the following expressions:

$$\left.\begin{aligned}
&A_C=\frac{A\cdot p_A}{100};\ A_{VF}=\frac{A\cdot m_A}{100};\ A_{AF}=\frac{A\cdot q_A}{100};\ A_{VP}=\frac{A\cdot r_A}{100};\\
&\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad A_{AP}=\frac{A\cdot s_A}{100}\\
&B_C=\frac{B\cdot p_B}{100};\ B_{VF}=\frac{B\cdot m_B}{100};\ B_{AF}=\frac{B\cdot q_B}{100};\ B_{VP}=\frac{B\cdot r_B}{100};\\
&\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad B_{AP}=\frac{B\cdot s_B}{100}\\
&C_C=\frac{C\cdot p_C}{100};\ C_{VF}=\frac{C\cdot m_C}{100};\ C_{AF}=\frac{C\cdot q_C}{100};\ C_{VP}=\frac{C\cdot r_C}{100};\\
&\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad C_{AP}=\frac{C\cdot s_C}{100}\\
&D_C=\frac{D\cdot p_D}{100};\ D_{VF}=\frac{D\cdot m_D}{100};\ D_{AF}=\frac{D\cdot q_D}{100};\ D_{VP}=\frac{D\cdot r_D}{100};\\
&\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad D_{AP}=\frac{D\cdot s_D}{100}
\end{aligned}\right\}\quad(4)$$

$$E_C=\frac{E\cdot p_E}{100};\ E_{VF}=\frac{E\cdot m_E}{100};\ E_{AF}=\frac{E\cdot q_E}{100};\ E_{VP}=\frac{E\cdot r_E}{100};$$
$$E_{AP}=\frac{E\cdot s_E}{100}$$
$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$
$$N_C=\frac{N\cdot p_N}{100};\ N_{VF}=\frac{N\cdot m_N}{100};\ N_{AF}=\frac{N\cdot q_N}{100};\ N_{VP}=\frac{N\cdot r_N}{100};$$
$$N_{AP}=\frac{N\cdot s_N}{100}$$

(cont'd)

(4)

From the conditions of the problem we know the quantity of proteins, fats and carbohydrates required in the diet, and also the quantity of these components contained in each product. On the basis of these facts we can form the equations: /374

$$\left.\begin{aligned}
a &= A_y + B_y + C_y + D_y + E_y + F_y + \ldots + N_C\\
b &= A_{VF} + B_{VF} + C_{VF} + D_{VF} +\\
&\quad + E_{VF} + F_{VF} + \ldots + N_{VF}\\
c &= A_{AF} + B_{AF} + C_{AF} + D_{AF} +\\
&\quad + E_{AF} + F_{AF} + \ldots + N_{AF}\\
d &= A_{VP} + B_{VP} + C_{VP} + D_{VP} +\\
&\quad + E_{VP} + F_{VP} + \ldots + N_{VP}\\
e &= A_{AP} + B_{AP} + C_{AP} + D_{AP} +\\
&\quad + E_{AP} + F_{AP} + \ldots + N_{AP}
\end{aligned}\right\}\quad (5)$$

After consideration of the expressions (4), the system of equations (5) will assume the following form:

$$\left.\begin{aligned}
a &= \frac{P_A}{100}A + \frac{P_B}{100}B + \frac{P_C}{100}C + \frac{P_D}{100}D +\\
&\quad + \frac{P_E}{100}E + \frac{P_F}{100}F + \ldots + \frac{P_N}{100}N\\
b &= \frac{m_A}{100}A + \frac{m_B}{100}B + \frac{m_C}{100}C + \frac{m_D}{100}D +\\
&\quad + \frac{m_E}{100}E + \frac{m_F}{100}F + \ldots + \frac{m_N}{100}N\\
c &= \frac{q_A}{100}A + \frac{q_B}{100}B + \frac{q_C}{100}C + \frac{q_D}{100}D +\\
&\quad + \frac{q_E}{100}E + \frac{q_F}{100}F + \ldots + \frac{q_N}{100}N\\
d &= \frac{r_A}{100}A + \frac{r_B}{100}B + \frac{r_C}{100}C + \frac{r_D}{100}D +\\
&\quad + \frac{r_E}{100}E + \frac{r_F}{100}F + \ldots + \frac{r_N}{100}N
\end{aligned}\right\}\quad (6)$$

$$e = \frac{s_A}{100}A + \frac{s_B}{100}B + \frac{s_C}{100}C + \frac{s_D}{100}D + \\ + \frac{s_E}{100}E + \frac{s_F}{100}F + \ldots + \frac{s_N}{100}N \Bigg\} \quad \text{(cont'd)} \quad (6)$$

For convenience in using system (6), we multiply both parts of the equations of this system by 100, and thus obtain /375

$$\left.\begin{aligned}
&1)\ 100a = p_A A + p_B B + p_C C + p_D D + \\
&\quad + p_E E + p_F F + \ldots p_N N \\
&2)\ 100b = m_A A + m_B B + m_C C + m_D D + \\
&\quad + m_E E + m_F F + \ldots + m_N N \\
&3)\ 100c = q_A A + q_B B + q_C C + q_D D + \\
&\quad + q_E E + q_F F + \ldots + q_N N \\
&4)\ 100d = r_A A + r_B B + r_C C + r_D D + \\
&\quad + r_E E + r_F F + \ldots + r_N N; \\
&5)\ 100e = s_A A + s_B B + s_C C + s_D D + \\
&\quad + s_E E + s_F F + \ldots + s_N N
\end{aligned}\right\} \quad (7)$$

Hence, from the specified conditions we have obtained a system of five equations with n unknowns (A, B, C, D, E, F, ... N). When the number of unknowns is greater than the number of linearly independent equations, the system has an infinite number of solutions, and these solutions may be both positive and negative.

We are interested only in the nonnegative solutions of the system.

Finding the nonnegative solution of the system means finding solutions for which the values of all unknown quantities are equal to zero or greater than zero, i.e., in our present case to satisfy the condition:

$$A \geq 0;\ B \geq 0;\ C \geq 0;\ D \geq 0;\ E \geq 0;\ \ldots;\ N \geq 0.$$

To find nonnegative solutions of the system of equations (7), we must adhere to the following order:

1. Transcribe the system of equations (7) in the form of a system of null-equations, which will have the following form:

$$\left.\begin{aligned}
&1)\ 0 = 100a - (p_A A + p_B B + p_C C + p_D D + \\
&\quad + p_E E + p_F F + \ldots p_N N) \\
&2)\ 0 = 100b - (m_A A + m_B B + m_C C + m_D D + \\
&\quad + m_E E + m_F F + \ldots + m_N N) \\
&3)\ 0 = 100c - (q_A A + q_B B + q_C C + q_D D + \\
&\quad + q_E E + q_F F + \ldots + q_N N) \\
&4)\ 0 = 100d - (r_A A + r_B B + r_C C + r_D D + \\
&\quad + r_E E + r_F F + \ldots + r_N N) \\
&5)\ 0 = 100e - (s_A A + s_B B + sc C + s_D D + \\
&\quad + s_E E + s_F F + \ldots + s_N N)
\end{aligned}\right\} \quad (8)$$

2. Select the basis unknowns (basis products), relative to which the system of equations should be solved. The number of basis unknowns must be equal to the number of equations. In our case there are five basis unknowns, for example, A, B, C, D, E. /376

3. Choose one of the basis unknowns for which the coefficients are positive (in one or several equations of the system); let us take, for example, the basis unknown A.

In null-equations the coefficients are considered to be positive if they are positive inside brackets.

4. Find the minimal value of the quotients obtained by dividing the free terms by the corresponding (positive only) coefficients for the selected unknown.

For example, if A is the unknown, let the coefficients in all the equations be positive, in which case the quotients obtained by dividing free terms by coefficients relative to A will have the values:

$$\frac{100a}{p_A};\ \frac{100b}{m_A};\ \frac{100c}{q_A};\ \frac{100d}{r_A};\ \frac{100e}{s_A}$$

and of these, let the quotient $100a/p_A$ have the least value.

5. Solve relative to the chosen basis unknown the null-equation in which the quotient obtained by dividing the free term by the coefficient of the chosen unknown has the least value.

In our example, having chosen A as the basis unknown, the quotient $100a/p_A$ has the least value and it applies to null-equation 1 of system (8), so that we may solve this null-equation with respect to A.

$$A=\frac{100a}{p_A}-\left(\frac{p_B}{p_A}B+\frac{p_C}{p_A}C+\frac{p_D}{p_A}D+\frac{p_E}{p_A}E+\frac{p_F}{p_A}F+\ldots+\frac{p_N}{p_A}N\right). \tag{9}$$

6. Substitute in the remaining null-equations of system (8) the expression for the solved basis unknown.

In our example we substitute expression (9) into null-equations 2, 3, 4 and 5 of system (8).

After substitution we have the following null-equations:

$$\left.\begin{aligned} 1)\ 0=100b-m_A\frac{100a}{p_A}-\left[\left(m_B-m_A\frac{p_B}{p_A}\right)B+\right.\\ +\left(m_C-m_A\frac{p_C}{p_A}\right)C+\left(m_D-m_A\frac{p_D}{p_A}\right)D+\left(m_E-m_A\frac{p_E}{p_A}\right)E+\\ \left.+\ldots+\left(m_N-m_A\frac{p_N}{p_A}\right)N\right]; \end{aligned}\right\} \tag{10}$$

$$
\left.\begin{aligned}
&2)\ 0=100c-q_A\frac{100a}{p_A}-\left[\left(q_B-q_A\frac{p_B}{p_A}\right)B+\right.\\
&+\left(q^C-q_A\frac{p_C}{p_A}\right)C+\left(q_D-q_A\frac{p_D}{p_A}\right)D+\left(q_E-q_A\frac{p_E}{p_A}\right)E+\\
&\left.+\ldots+\left(q_N-q_A\frac{p_N}{p_A}\right)N\right];\\
&3)\ 0=100d-r_A\frac{100a}{p_A}-\left[\left(r_B-r_A\frac{p_B}{p_A}\right)B+\right.\\
&+\left(r_C-r_A\frac{p_C}{p_A}\right)C+\left(r_D-r_A\frac{p_D}{p_A}\right)D+\\
&\left.+\left(r_E-r_A\frac{p_E}{p_A}\right)E+\ldots+\left(r_N-r_A\frac{p_N}{p_A}\right)N\right];\\
&4)\ 0=100e-s_A\frac{100a}{p_A}-\left[\left(s_B-s_A\frac{p_B}{p_A}\right)B+\right.\\
&+\left(s_C-s_A\frac{p_C}{p_A}\right)C+\left(s_D-s_A\frac{p_D}{p_A}\right)D+\\
&\left.+\left(s_E-s_A\frac{p_E}{p_A}\right)E+\ldots+\left(s_N-s_A\frac{p_N}{p_A}\right)N\right].
\end{aligned}\right\}
$$

(cont'd) (10)

7. From the null-equations (10) thus obtained, in a similar manner we find the next basis unknown and substitute its expression both in the unused null-equations and in the expressions of the previously solved basis unknowns (in our example in expression (9) for A). /377

We carry out such operations until we have all the expressions for the basis unknowns which contain only a free term and nonbasis unknowns.

In our example the expression will have the form:

$$
\left.\begin{aligned}
A&=Q_A-f_A(F, G, H, \ldots, N.)\\
B&=Q_B-f_B(F, G, H, \ldots N.)\\
C&=Q_C-f_C(F, G, H, \ldots N.)\\
D&=Q_D-f_D(F, G, H, \ldots N.)\\
E&=Q_E-f_E(F, G, H, \ldots N.),
\end{aligned}\right\} \qquad (11)
$$

where Q_A, Q_B, Q_C, Q_D and Q_E are positive free terms, and f_A, f_B, f_C, f_D and f_E are functions of nonbasis unknowns.

These expressions are the solution to the system of equations (7) satisfying the conditions laid down when the equations were formed.

If the free term is negative in any of the equations for the basis product, this means that this basis product is incompatible with the other chosen basis products for satisfying the specified conditions. In that case we must change one of the basis products (any one) and derive the formulas again. The product which previously was a basis product will now appear in the new formulas as a nonbasis product. /378

The equations (11) can be used to select from available food products a diet of specified calorific value and with specified relative proportions of proteins, fats and carbohydrates.

A specified diet can be selected either from basis products only or from basis and nonbasis products.

TABLE 1. List of Products and Their Chemical Composition

Product	Chemical Composition, %						
	C	VF	AF	VP	AP	Water	Other (Ash, Cellulose)
A_1 — Sweet Potato	23.5	—	—	2.0	—	72.0	2.5
A_2 — Potato	21.0	—	—	2.0	—	75.0	2.0
A_3 — Cabbage	5.4	—	—	1.8	—	90.0	2.8
A_4 — Beetroot	10.8	—	—	1.3	—	86.0	1.9
A_5 — Carrot	8.0	—	—	1.5	—	88.5	2.0
A_6 — Onion	9.6	—	—	3.0	—	86.0	1.4
A_7 — Lettuce	2.2	—	—	1.5	—	95.0	1.3
A_8 — Dill	7.5	—	—	2.5	—	84.7	5.3
A_9 — Parsley	11.0	—	—	1.5	—	85.0	2.5
A_{10} — Peanut	15.5	44.5	—	27.5	—	7.5	5.0
A_{11} — Chlorella	7.0	3.0	—	15.0	—	70.0	5.0
A_{12} — Beef	—	—	11.0	—	81.0	4.0	4.0
A_{13} — Cream Cheese	6.0	—	50.0	—	33.0	4.0	7.0
A_{14} — Cream	30.1	—	43.2	—	20.0	2.7	4.0
A_{15} — Chocolate	53.2	37.2	—	6.3	—	1.0	2.3
A_{16} — Powdered Egg	1.8	—	99.5	—	44.0	8.5	3.5
A_{17} — Cows' Butter	—	—	—	—	—	0.5	—
A_{18} — Almonds	10.0	55.0	—	21.0	—	8.0	6.0
A_{19} — Vegetable Oil	—	99.9	—	—	—	0.1	—
A_{20} — Buckwheat	73.8	1.8	—	8.5	—	14.0	1.9
A_{21} — Rice	75.8	1.0	—	7.6	—	14.0	1.6
A_{22} — Sugar	99.9	—	—	—	—	0.1	—
A_{23} — Wheat Flour	72.9	1.1	—	11.0	—	14.0	1.0

In the first case, in Eqs. (11) we must represent all nonbasis products as equal to zero, in which case the basis products taken in amounts determined by the free terms will constitute the specified ration. If it is desired to include in the diet one (or several) nonbasis products in addition to the basis products, we must specify the quantity of nonbasis product (or products) needed and substitute this value (or these values) in Eqs. (11). Solution to Eqs. (11) will then show us the quantities of basis products we must take in order to secure the specified diet, making allowance for the nonbasis products taken in addition. /379

The quantity of any nonbasis product which may be taken can only be that which, if substituted into Eqs. (11), does not give a negative solution in any of the equations.

To explain the technique of calculating a required diet more clearly and to demonstrate its possibilities, let us solve several concrete examples.

EXAMPLE

Problem. Compile a diet with a total calorific value of 2700 kcal and with the ratio P : F : C = 1.25: 1: 4.72.

Of the total protein content, VP = 40% and AP = 60%, and of the total fat content AF = 80% and VF = 20%.

To form this diet, the products listed in Table 1, items 1 to 19 inclusive, are to be used.

Solution. By means of Eqs. (3) we determine the quantity of proteins, fats and carbohydrates needed to satisfy the specified calorific value: P = 100 g, F = 80 g, C = 377 g.

By calculating the proportions we obtain the quantities of VP, AP, VF and AF: VP = 40 g, AP = 60 g, VF = 16 g, AF = 64 g.

We have thus found that to satisfy the specified calorific value and the specified proportions of proteins, fats, and carbohydrates, we must have: carbohydrates (a) = 377 g; vegetable fats (b) = 16 g; animal fats (c) = 64 g; vegetable proteins (d) = 40 g; animal proteins (e) = 60 g.

Using the data in Table 2 and Eqs. (8), we form the null-equations of the system (it will be noted that in Table 2, for convenience, the products are denoted by the one letter A with the index number of the product).

When solving problems such as this, it is desirable to list the specified products in a table similar to Table 1, for this greatly facilitates the formation of the null-equation, because all coefficients of each null-equation are then found in one column only. For example, for the null-equation of carbohydrates [Eq. (1) of system (8)] they are in Column C, for the null-equation of vegetable fats [Eq. (2) of the system (8)] they are in column FV, and so on.

The null-equations of our example include 19 specified products.

$$\left.\begin{aligned}
&1.\ 0 = 37700 - (23.5\,A_1 + 21\,A_2 + 5.4\,A_3 + 10.8\,A_4 + \\
&+ 8A_5 + 9.6\,A_6 + 2.2\,A_7 + 7.5A_8 + 11\,A_9 + 15.5\,A_{10} + \\
&+ 7\,A_{11} + 6\,A_{13} + 30.1\,A_{14} + 53.2\,A_{15} + 1.8\,A_{16} + 10\,A_{18});\\
&2.\ 0 = 1600 - (44.5\,A_{10} + 3\,A_{11} + 37.2\,A_{15} + \\
&+ 55\,A_{18} + 99.9\,A_{19})\\
&3.\ 0 = 6400 - (11\,A_{12} + 50\,A_{13} + 43.2\,A_{14} + \\
&+ 42.2\,A_{16} + 99.5\,A_{17})\\
&4.\ 0 = 4000 - (2\,A_1 + 2\,A_2 + 1.8A_3 + 1.3\,A_4 + 1.5\,A_5 + \\
&+ 3\,A_6 + 1.5\,A_7 + 2.5\,A_8 + 1.5\,A_9 + 27.5\,A_{10} + 15\,A_{11} + \\
&+ 6.3\,A_{15} + 21\,A_{18})\\
&5.\ 0 = 6000 - (81\,A_{12} + 33\,A_{13} + 20\,A_{14} + 44\,A_{16})
\end{aligned}\right\} \quad (12)$$

Let us choose as our basis products: A_1 (sweet potato), A_{11} (Chlorella), A_{12} (beef), A_{15} (chocolate) and A_{17} (cows' butter). /380

Using the order of solution of the system of equations given above for seeking nonnegative solutions, we obtain working formulas corresponding to Eqs. (11) for our chosen basis products A_1, A_{11}, A_{12}, A_{15} and A_{17}, by means of which we can draw up the specified diet composed of the necessary products.

$$\begin{aligned}
A_1 &= 1501.7 - (0.89228\,A_2 + 0.21915\,A_3 + 0.45691\,A_4 + \\
&+ 0.33335\,A_5 + 0.3904\,A_6 + 0.08314\,A_7 + 0.30145\,A_8 + 0.4645\,A_9 + \\
&- 2.241\,A_{10} + 0.2591\,A_{13} + 1.3008\,A_{14} + 0.07796\,A_{16} - \\
&- 3.0705\,A_{18} - 6.06\,A_{19});\\
A_{11} &= 50 - (0.014847\,A_2 + 0.093932\,A_3 + 0.026664\,A_4 + \\
&+ 0.05757\,A_5 + 0.15322\,A_6 + 0.092115\,A_7 + 0.1515\,A_8 + \\
&+ 0.039392\,A_9 + 1.685\,A_{10} - 0.035754\,A_{13} - 0.179785\,A_{14} - \\
&- 0.010794\,A_{16} + 1.2302\,A_{18} - 0.335\,A_{19});\\
A_{12} &= 74.1 - (0.407\,A_{13} + 0.247\,A_{14} + 0.544\,A_{16});\\
A_{15} &= 39 - (-0.001195\,A_2 - 0.00757\,A_3 - 0.00215\,A_4 - \\
&- 0.00464\,A_5 - 0.01235\,A_6 - 0.00744\,A_7 - 0.0122\,A_8 - \\
&- 0.00318\,A_9 + 1.059\,A_{10} + 0.00288\,A_{13} + 0.0145\,A_{14} + \\
&+ 0.000866\,A_{16} + 1.38\,A_{18} + 2.72\,A_{19});\\
A_{17} &= 56.1 - (0.458\,A_{13} + 0.406\,A_{14} + 0.364\,A_{16}).
\end{aligned}$$

Let us now test the accuracy of the equations used for choosing the diets. /381

Let us assume that the diet must consist of basis products only. In that case, taking all nonbasis products equal to zero, by means of the working formulas we determine the necessary number of grams of basis products for the diet.

$$A_1 = 1501.7 \text{ g}$$
$$A_{11} = 50 \text{ g}$$
$$A_{12} = 74.1 \text{ g}$$
$$A_{15} = 39 \text{ g}$$
$$A_{17} = 56.1 \text{ g}$$

Knowing the percentage content of all components of each product (Table 1), we can determine the content of each component in grams in the whole diet and compare the result with that given. These calculations are shown in Table 2, and it is clear that the chosen diet fully satisfies all the specified requirements.

TABLE 2. Results of Calculation for Basis Products

Product	Weight of Product, g	C, g	VF, g	AF, g	VP, g	AP, g
A1 — Sweet Potato . . .	1501,7	352,75	—	—	30	—
A11 — Chlorella	50,0	3,5	1,5	—	7,5	—
A12 — Beef	74,1	—	—	8,15	—	60
A15 — Chocolate	39,0	20,75	14,5	—	2,5	—
A17 — Cows' Butter . . .	56,1	—	—	55,85	—	—
Total	—	377	16	64	40	60
Specified		377	16	64	40	60

Total Calorific Value . . . . . 2700 kcal

Commas represent decimal points.

Let us now assume that, besides basis products, the diet must include one nonbasis product, namely, onion in an amount of 50 g, i.e., $A_6 = 50$ g. Then, making all nonbasis products equal to zero except for $A_6 = 50$ g, by the working formulas we have:

$$A_1 = 1501.7 - 0.3904 \cdot 50 = 1482.2 \text{ g},$$
$$A_{11} = 50 - 0.15322 \cdot 50 = 42.3 \text{ g},$$
$$A_{12} = 74.1 \text{ g},$$
$$A_{15} = 39 + 0.01235 \cdot 50 = 39.6 \text{ g},$$
$$A_{17} = 56.1 \text{ g}.$$

All the checking calculations for this diet are given in Table 3, which shows that this diet also completely satisfies the specified demands.

This example is given to assist in explaining the method of calculation and /382
to show how it can be used, in principle, to choose a diet of specified calorific

value and with specified proportions of proteins, fats and carbohydrates from a limited assortment of products.

TABLE 3. Results of Calculation for Basis Products and One Nonbasis Product (Onion)

Product	Weight of Product, g	C, g	VF, g	AF, g	VP, g	AP, g
A_0 — Onion	50	4,8	—	—	1,5	—
A_1 — Sweet Potato . . .	1482,2	348,2	—	—	29,7	—
A_{11} — Chlorella	42,32	3,0	1,27	—	6,35	—
A_{12} — Beef.	74,1	—	—	8,15	—	60
A_{15} — Chocolate	39,617	21,0	14,73	—	2,45	—
A_{17} — Cows' Butter . . .	56,1	—	—	55,85	—	—
Total		377	16	64	40	60
Specified		377	16	64	40	60

Total Calorific Value . . . . . 2700 kcal

Commas represent decimal points.

The specialist must determine precisely which products and how much of each product must be taken from a given assortment, on the basis of the formulas obtained in order to adhere approximately (or perhaps exactly) to the intended menu.

It will be clear from the examples given above that, being in possession of working formulas, it is possible to determine the proportions in which necessary products from a limited assortment must be taken in order to ensure that the diet for selected menus conforms to the specified calorific value and specified content of proteins, fats and carbohydrates.